

# GEOGRAPHIC AND HOST DISTRIBUTION OF BLOOD PARASITES IN COLUMBORID BIRDS

NORMAN D. LEVINE

University of Illinois, Urbana

## SYNOPSIS

Available data on geographic distribution and incidence of blood parasites in different host species of columborid birds in the wild are assembled from 174 reports in the literature, analyzed, and information on life cycles and pathogenesis is given. The most common genus is *Haemoproteus*, of which two species occur in naturally affected birds. The more common species is *H. columbae*, the gametocytes of which extend along one side of the host erythrocyte and curve around its ends. It has been found in 14 host species in 24 countries. *H. sacha- rovi* has gametocytes which completely fill the host cell when mature. It has been found in 3 host species in the United States and Italy.

*Trypanosoma avium* has been reported from 7 host species in 6 countries.

Three species of *Plasmodium* have been reported. *P. relictum* is by far the most common; it has been found in 3 host species in 5 countries. *P. elongatum* has been found in 1 host species (*Zenaidura macroura*) in the United States. *P. hexamerium* has also been found in *Z. macroura* in the United States and possibly also in *Columbigallina talpacoti* in Colombia.

*Leucocytozoon marchouxi*, which has rounded gametocytes, has been reported from 13 host species in 15 countries. A species of *Leucocyto-*

*zoon* with elongate gametocytes has been seen once in Uganda. *Leucocytozoon* has not been reported from South or Central America despite the fact that a number of surveys have been made there.

*Toxoplasma gondii* has been identified by mouse inoculation or dye test or both in 8% of 176 domestic pigeons in 4 surveys in different parts of the United States. What may have been *Toxoplasma*, *Lankesterella* or possibly some other genus has been found in 3 host species in 4 countries. The possible role of the domestic pigeon as a reservoir of *Toxoplasma gondii* is mentioned.

The distribution of blood protozoa in columborid birds is poorly known. *Haemoproteus* has been reported from only 20% of the known 61 genera and 8% of the known 320 species of these birds, *Plasmodium* has been found in 11% of the genera and 3% of the species, *Leucocytozoon* in 10% of the genera and 4% of the species, *Trypanosoma* in 8% of the genera and 2% of the species, and *Toxoplasma* or a similar form in 3% of the genera and 1% of the species. The parasite species has been identified in only 58% of 138 reports of *Haemoproteus*, 62% of 26 reports of *Plasmodium*, 35% of 26 reports of *Leucocytozoon*, 60% of 10 reports of *Trypanosoma*, and 77% of 13 reports of *Toxoplasma* and similar forms. In 43% of the total of 213 records, the species name of the parasite was not given. In only 41 (24%)

of the 173 papers were 10 or more birds of a single species examined, and in only 12 (7%) of them were 100 or more birds examined.

#### INTRODUCTION

Our present information on the blood parasites of birds of the order Columboida is, with a few exceptions, both scattered and scanty. It has been tabulated by Levine and Kantor (1959), and the analyses in the present paper are based primarily on the raw data in their tables. Additional information from other papers has been included as indicated. The only references given at the end of this paper are to the papers specifically discussed in the text; all others and the sources of all data can be found in Levine and Kantor (1959). Records of blood parasites from birds in zoos have not been tabulated, since they do not necessarily mirror the true situation in the wild. The surveys discussed in the text are for the most part only those in which 100 or more birds were examined. The results of surveys in which fewer birds were examined are given in the tables.

*Trypanosoma*. Trypanosomes were first found in columboid birds by Novy and MacNeal (1905a, b) in mourning doves (*Zenaidura macroura*) in Michigan; they thought that they were probably *Trypanosoma avium*. De Mello and Bras de Sa (1916) found a trypanosome which they named *Trypanosoma hannai* in domestic pigeons (*Columba livia*) in Portuguese India, and Sergent (1941a, b) found a trypanosome which he named *T. oenae* in *Oena capensis* in the Nigerian Sahara.

Wood and Herman (1943) and Coatsney and West (1938) used the name *T. avium* for the trypanosomes which they found in *Zenaida asiatica mearnsi* in Arizona and in *Zenaidura* sp. in Nebraska, respectively.

*Trypanosoma avium* Danilewsky, 1885 was first described from owls (scientific name not given) and roller-birds (*Coracias garrulus*) in Europe, and has since been reported from a wide variety of birds. Various other names have been given to trypanosomes in other birds, largely on the basis of their presence in a different host from those previously reported. The validity of most of these names, including *T. hannai* and *T. oenae*, is highly questionable.

Bennett (1961) studied the morphology of trypanosomes from 25 species of birds belonging to 11 families (but not including any columboid birds), and concluded that they were all the same species except for a trypanosome which he found once in a chipping sparrow (*Spizella passerina*); he considered the chipping sparrow form to be *Trypanosoma paddae* Laveran and Mesnil, 1904 and all the others to be *T. avium*.

Cross transmission studies on avian trypanosomes have been carried out by Baker (1956a, b) and Bennett (1961). The former transmitted *T. avium* from the rook (*Corvus frugilegus*) and jackdaw (*Collocalia monedula*) to canaries, but failed to transmit it to a single 3-day-old chick. Bennett (1961) transmitted strains of *T. avium* by means of simuliids or *Aedes aegypti* from 9 species of birds belonging to 4 orders into 15 species of birds belonging to 5 orders. Many of these trans-

missions were from birds of one order to those of another. Bennett made no attempt to infect every receptor host species with a strain from every donor host species, but used enough combinations to show that it would have been possible. Among them, he infected the pigeon with strains from the blue jay and saw-whet owl.

On the basis of the above morphologic and cross-transmission studies, it is safe to conclude that *Trypanosoma avium* occurs widely in many different orders of birds and that, unless they are proven to be different, all avian trypanosomes should be referred to this species.

Blood-sucking arthropods such as

blackflies, mosquitoes and hippoboscids are the vectors of avian trypanosomes. Baker (1956a, b) worked out the life cycle of *T. avium* from rooks and jackdaws. He found that in England the hippoboscid fly, *Ornithomyia avicularia*, acts as the vector and that birds become infected when they eat insects which have become infected by sucking blood. According to Baker, there is no multiplication in the avian host, the trypanosomes simply becoming larger; multiplication takes place only in the arthropod host.

Bennett and Fallis (1960) compared the incidence and level of parasitemia of *Trypanosoma* with the occurrence and feeding habits of

TABLE 1.—Known Geographic Distribution and Prevalence of *Trypanosoma* in Columborid Birds.

Country	Bird Species	Prevalence (%)		
		Present but no reliable figures on prevalence	Surveys in which more than 10 birds were examined	Surveys in which 100 or more birds were examined
EUROPE				
Germany.....	<i>Columba palumbus</i> .....		24	24
ASIA				
Portuguese India..	<i>Columba livia</i> .....	+		
West Java.....	<i>Streptopelia chinensis</i> .....		8	8
AFRICA				
Nigerian Sahara...	<i>Oena capensis</i> .....	+		
Gambia.....	<i>Streptopelia vinacea</i> .....	+		
NORTH AMERICA				
Arizona.....	<i>Zenaidura asiatica mearnsi</i> .....		8	
U. S. A.....	<i>Zenaidura macroura carolinensis</i> .....		0.5	0.5
Michigan.....	<i>Zenaidura macroura carolinensis</i> .....	+		
Nebraska.....	<i>Zenaidura macroura carolinensis</i> .....	+		

TABLE 2.—Known Geographic Distribution and Prevalence of *Plasmodium* in Columboid Birds.

Country	Bird Species	<i>Plasmodium</i> Species	Prevalence (%)		
			Present but no reliable figures on prevalence	Surveys in which more than 10 birds were examined	Surveys in which 100 or more birds were examined
<b>EUROPE</b>					
Germany.....	<i>Columba palumbus</i>	<i>relictum</i> .....		48	48
Czechoslovakia....	<i>Columba palumbus</i>	sp.....	+		
<b>ASIA</b>					
Japan.....	<i>Streptopelia orientalis</i>	sp.....		13	13
<b>AFRICA</b>					
Egypt.....	<i>Columba livia</i>	<i>relictum</i> .....	+		
French Congo....	<i>Columba livia</i>	<i>relictum</i> .....	+		
Algeria.....	<i>Streptopelia turtur</i>	sp.....	+		
Belgian Congo....	<i>Treron calva</i>	sp.....	+		
<b>NORTH AMERICA</b>					
U. S. A.....	<i>Columba livia</i>	<i>relictum</i> .....	+		
California.....	<i>Columba livia</i>	<i>relictum</i> .....		5	
Iowa.....	<i>Columba livia</i>	<i>relictum</i> .....		20	
Arizona.....	<i>Zenaidura macroura</i>	<i>relictum</i> .....			
U. S. A.....	<i>Zenaidura macroura</i>	sp.....		83	
U. S. A.....	<i>Zenaidura macroura</i>	<i>elongatum</i> .....		1	1
U. S. A.....	<i>Zenaidura macroura</i>	<i>relictum</i> .....	+		
Illinois.....	<i>Zenaidura macroura</i>	sp.....		0.5	0.5
Nebraska.....	<i>Zenaidura macroura</i>	<i>hexamerium</i> .....		1	1
D. C. & vicinity..	<i>Zenaidura macroura</i>	<i>relictum</i> .....		9	
California.....	<i>Zenaidura macroura</i>	sp.....	+		
Mexico.....	<i>Zenaidura macroura</i>	<i>relictum</i> .....		1	1
	<i>Leptotila verreauxi</i>	sp.....	+		
<b>SOUTH AMERICA</b>					
Colombia.....	<i>Columba cayennensis</i>	sp.....		5	
Uruguay.....	<i>Columba livia</i>	<i>relictum</i> .....	+		
Colombia.....	<i>Columbigallina talpacoti</i>	<i>hexamerium</i> .....	+		
		(?)			

various ornithophilic flies in Algonquin Park, Canada, and concluded that the vectors are probably simuliids. Their study did not include any columborid birds. Bennett (1961) found that several species of simuliid flies and also, *Aedes aegypti* could act as vectors of *T. avium*. Leptomonad, crithidial and metacyclic trypanosome forms developed in the midgut and hindgut of the simuliids, and infection took place when trypanosomes which had been passed in the feces entered the host thru breaks in the skin produced by the feeding flies. Bennett's experiments indicated that birds could be infected by eating flies only if the insects were crushed enough to release flagellates from the hindgut into the birds' mouths.

Nothing is known of the pathogenicity of avian trypanosomes. They are presumably non-pathogenic.

The known geographic distribution and prevalence of *T. avium* in columborid birds are shown in Table I. Only three surveys have been reported in which 100 or more birds were examined, and only four in which more than 10 birds were examined. Böing (1925) found *Trypanosoma* sp. in 24% of 128 *Columba palumbus* in Germany; Kraneveld and Mansjoer (1954) reported it in 8% of 2100 *Streptopelia chinensis tigrina* in West Java; Huff (1939) reported it in 0.5% of 188 *Zenaidura macroura carolinensis* in the United States; and Wood and Herman (1943) reported *Trypanosoma avium* in 8% of 12 *Zenaida asiatica mearnsi* in Arizona. (As the result of a printing error, the host species was listed by Levine and Kantor (1959) as *Zenaidura macroura*; actually,

Wood and Herman found no trypanosomes in the 27 *Z. macroura* which they examined.)

To these surveys should be added several in which no trypanosomes were found, such as that of Hanson *et al.* (1957) in mourning doves in Illinois; these can be identified by comparison with the data on *Haemoproteus* (Table 3).

*Plasmodium*. Three species of *Plasmodium* have been reported from naturally infected columborid birds in the wild. *P. relictum* is by far the most common. Böing (1925) found it in 48% of 128 *Columba palumbus* in Germany; Herman *et al.* (1954) found it in 5% of 43 *Columba livia* and 1% of 383 *Zenaidura macroura* in Kern County, California; Mathey (1955) found it in 3 *C. livia* in the Sacramento area of California; Becker, Hollander and Pattillo (1956) found it in 20% of 15 *C. livia* in Iowa; and Coatney (1938) found it in 9% of 11 *Zenaidura macroura* in Nebraska. In addition, it has been reported from *Columba livia* in Egypt, the French Congo and Uruguay.

*Plasmodium elongatum* was found in 1% of 188 *Zenaidura macroura carolinensis* from the United States by Huff (1939), and *P. hexamerium* was found in 1% of 134 *Z. macroura carolinensis* in Illinois by Huff (1935). Renjifo-Salcedo, Sanmartin and Zulueta (1952) found a *Plasmodium* which they thought might be *P. hexamerium* in 17% of 6 *Columbigallina talpacoti* in Colombia.

In addition to the above 3 species, mention should be made of the form which Carini (1912) described under the name *Plasmodium columbae* from a pigeon which had died of toxoplas-

miosis following experimental infection with a canine strain of *Toxoplasma gondii*. Its gametocytes were halter-shaped and resembled those of *Haemoproteus columbae*; in addition to these, Carini found many round, oval or halter-shaped parasites with slender cytoplasmic extensions or pseudopods. Carini was not sure that he was actually dealing with a *Plasmodium*, since he saw no schizonts. In the absence of confirmation in the ensuing 49 years, *Plasmodium columbae* cannot be accepted as a valid species or even as a *Plasmodium*. I consider the name a *nomen nudum*.

In addition to the named species, *Plasmodium* sp. has been found in *Columba palumbus* in Czechoslovakia, in 13% of 111 *Streptopelia orientalis* in Japan by Ogawa (1912), in *Streptopelia turtur* in Algeria, in *Treron calva* in the Belgian Congo, in *Zenaidura asiatica mearnsi* in Arizona, in 0.5% of 188 *Zenaidura macroura carolinensis* in the U. S. by Huff (1939), in *Leptotila vereauxi* in Mexico, and in *Columba cayennensis* in Colombia.

Wolfson (1937, 1940) infected domestic pigeons (*Columba livia*) experimentally with *P. cathemerium*, and Huff *et al.* (1950) and Huff and Marchbank (1955) infected domestic pigeons experimentally with *P. fallax*.

The known geographic distribution and prevalence of *Plasmodium* in columborid birds are shown in Table 2. The results of surveys in which 100 or more birds were examined have been given above. There have been only 5; in Germany, Japan, California, Illinois and the U. S. in

general. To these should be added several surveys in which no *Plasmodium* was found, such as that of Hanson *et al.* (1957) in mourning doves in Illinois; these can be identified by comparison with the data on *Haemoproteus* (Table 3).

In sum, *Plasmodium relictum* has been found in the wild in *Columba livia*, *C. palumbus* and *Zenaidura macroura*. It has also been reported in zoos in *Columba argentina*, *Ducula concinna*, *Leptotila crumeniferus*, *Megaloprepia magnifica*, *Scardafella squammata*, *Tympanistria bicolor*, and *T. tympanistria*. *Plasmodium elongatum* has been reported only from the mourning dove, *Zenaidura macroura*. *Plasmodium hexamerium* has been reported with certainty from *Z. macroura* and questionably from *Columbigallina talpacoti*. Unidentified species of *Plasmodium* have been reported in *Columba palumbus*, *C. cayennensis*, *Leptotila vereauxi*, *Streptopelia orientalis*, *S. turtur*, *Zenaidura asiatica mearnsi* and *Zenaidura macroura* in the wild, and in *Columba squamosa*, and *Tympanistria tympanistria* in zoos. In all, *Plasmodium* has been found in a total of 10 identified species of columborid birds in the wild, and in 9 others in zoos.

*Haemoproteus*. This is by far the most common genus of blood protozoon in columborid birds. Two species occur in naturally infected birds in the wild. The more common one is *H. columbae*, which has so-called halter-shaped gametocytes which extend along one side of the host cell nucleus and curve around its ends. This species was originally described by Celli and Sanfelice (1891a, b) from the domestic pigeon and has

TABLE 3.—Known Geographic Distribution and Prevalence of *Haemoproteus*\* in Columborid Birds.

Country	Bird Species	Prevalence (%)		
		Present but no reliable figures on prevalence	Surveys in which more than 10 birds were examined	Surveys in which 100 or more birds were examined
<b>EUROPE</b>				
Greece	<i>Columba livia</i>		18	
Italy	<i>Columba livia</i>		83	
Spain	<i>Columba livia</i>	+		
Italy	<i>Columba oenas</i>	+		
Germany	<i>Columba palumbus</i>		20	20
England	<i>Columba palumbus</i>	+		
Greece	<i>Streptopelia decaocto</i>		23	
Italy	<i>Streptopelia turtur</i>		3	
Spain	<i>Streptopelia turtur</i>		73	
Germany	<i>Streptopelia turtur</i>	+		
<b>ASIA</b>				
Lebanon	<i>Columba livia</i>	+		
"Plains," India	<i>Columba livia</i>		100	
Delhi, India	<i>Columba livia</i>		22	22
Portuguese India	<i>Columba livia</i>	+		
Manila, Philippines	<i>Columba livia</i>		81	
Wellesley Province India	<i>Columba</i> sp.		100	
Palestine	<i>Columba</i> sp.	+		
Philippines	<i>Columba</i> sp.	+		
Mukteswar, India	<i>Sphenurus sphenurus</i>	+		
Formosa	<i>Streptopelia chinensis</i>	+		
Tonkin, Vietnam	<i>Streptopelia tranquebarica</i>	+		
India	<i>Streptopelia turtur</i>	+		
<b>AFRICA</b>				
French Sudan	<i>Columba guinea</i>	+		
Algeria	<i>Columba livia</i>	+		
Egypt	<i>Columba livia</i>	+		
French Morocco	<i>Columba livia</i>		45	
French Congo	<i>Columba livia</i>	+		
Belgian Congo	<i>Columba livia</i>	+		
Portuguese Guinea	<i>Columba livia</i>	+		
Un. S. Africa	<i>Columba livia</i>	+		
Ethiopia	<i>Oena capensis</i>	+		
Un. S. Africa	<i>Oena capensis</i>	+		
Mozambique	<i>Plectropterus gambiensis</i>	+		
Un. S. Africa	<i>Streptopelia capicola</i>	+		
Ethiopia	<i>Streptopelia decipiens</i>	+		
Belgian Congo	<i>Streptopelia semitorquata</i>	+		
Liberia	<i>Streptopelia semitorquata</i>	+		
French Sudan	<i>Streptopelia senegalensis</i>	+		
Gambia	<i>Streptopelia senegalensis</i>	+		
Algeria	<i>Streptopelia turtur</i>	+		

TABLE 3.—Continued

Country	Bird Species	Prevalence (%)		
		Present but no reliable figures on prevalence	Surveys in which more than 10 birds were examined	Surveys in which 100 or more birds were examined
French Morocco	<i>Streptopelia turtur</i>		40	
French Sudan	<i>Streptopelia vinacea</i>	+		
Gambia	<i>Streptopelia vinacea</i>	+		
Belgian Congo	<i>Treron calva</i>	+		
Gambia	<i>Treron calva</i>	+		
NORTH AMERICA				
Ariz. & Calif.	<i>Columba fasciata</i>	+		
Colorado	<i>Columba fasciata</i>		80	
California	<i>Columba livia</i>	+		
D.C., Md., Va.	<i>Columba livia</i>	+		
Florida	<i>Columba livia</i>	+		
Hawaii	<i>Columba livia</i>	+		
Iowa	<i>Columba livia</i>	+		
Iowa	<i>Columba livia</i>		15**	
Nebraska	<i>Columba livia</i>		22**	
Pennsylvania	<i>Columba livia</i>	+		
South Carolina	<i>Columba livia</i>	+		
U.S.A.	<i>Columba livia</i>		100	
U.S.A.	<i>Columba livia</i>	+++		
Mexico	<i>Columba livia</i>	+		
Arizona	<i>Zenaidura asiatica</i>		33	
Mexico	<i>Zenaidura asiatica</i>	+		
Ariz. & Calif.	<i>Zenaidura macroura</i>		93	
Ariz. & Calif.	<i>Zenaidura macroura</i>		41**	
Northern Calif.	<i>Zenaidura macroura</i>	+		
Northern Calif.	<i>Zenaidura macroura</i>	+++		
Southern Calif.	<i>Zenaidura macroura</i>	+		
D. C. & vicinity	<i>Zenaidura macroura</i>	+++		
Georgia	<i>Zenaidura macroura</i>		25	
Georgia	<i>Zenaidura macroura</i>	+		
Illinois	<i>Zenaidura macroura</i>	+		
Illinois	<i>Zenaidura macroura</i>		25-43	25-43
Illinois	<i>Zenaidura macroura</i>	+++		
Illinois	<i>Zenaidura macroura</i>		43-58**	43-58**
Massachusetts	<i>Zenaidura macroura</i>		7**	
Massachusetts	<i>Zenaidura macroura</i>		8	
Michigan	<i>Zenaidura macroura</i>	+		
Michigan	<i>Zenaidura macroura</i>	+++		
Nebraska	<i>Zenaidura macroura</i>	+		
Nebraska	<i>Zenaidura macroura</i>		20	
Nebraska	<i>Zenaidura macroura</i>	+++		
Nebraska	<i>Zenaidura macroura</i>		67**	
Texas	<i>Zenaidura macroura</i>		56	56
Texas	<i>Zenaidura macroura</i>		27**	27**
Texas	<i>Zenaidura macroura</i>		74	74
U.S.A. (mostly Illinois)	<i>Zenaidura macroura</i>		47	47
U.S.A. (mostly Illinois)	<i>Zenaidura macroura</i>		56**	56**

TABLE 3.—Concluded

Country	Bird Species	Prevalence (%)		
		Present but no reliable figures on prevalence	Surveys in which more than 10 birds were examined	Surveys in which 100 or more birds were examined
SOUTH AND CENTRAL AMERICA				
Colombia	<i>Columba cayennensis</i>	+		
Colombia	<i>Columba cayennensis</i>		71	
Brazil	<i>Columba livia</i>	+		
Brazil	<i>Columba livia</i>		58	58
Brazil	<i>Columba livia</i>		15	
French Guiana	<i>Columba livia</i>	+		
Uruguay	<i>Columba livia</i>	+		
Argentina	<i>Columba picazuro</i>	+		
Brazil	<i>Columba picazuro</i>	+		
Brazil	<i>Columba rufina</i>	+		
Brazil	<i>Columba rufina</i>		92	
French Guiana	<i>Columba rufina</i>	+		
Brazil	<i>Columba</i> sp.	+		
Brazil	<i>Columbigallina talpacoti</i>	+		
Colombia	<i>Columbigallina talpacoti</i>	+		
Venezuela	<i>Columbigallina talpacoti</i>	+		
Argentina	<i>Columbigallina picui</i>		20	20
Brazil	<i>Columbigallina picui</i>	+		
Brazil	<i>Leptoptila</i> sp.	+		
Brazil	<i>Scardafella squammata</i>	+		
El Salvador	<i>Zenaida asiatica</i>	+		
Argentina	<i>Zenaidura auriculata</i>	+		
Colombia	<i>Zenaidura auriculata</i>	+		
AUSTRALIA	<i>Ptilinopus superbus</i>	+		

\* *H. columbae* unless otherwise indicated.

\*\* *H. sacharovi*.

since been found in many other columborid birds.

Separate specific names have been given to morphologically indistinguishable forms in some hosts: *H. maccallumi* by Novy and MacNeal (1905a) to the form in *Zenaidura macroura*, *H. melopeliae* by Layeran and Petit (1909) to the form in *Zenaida asiatica*, *H. turtur* by Covaleda Ortega and Gallego Berenguier (1950) to the form in *Strepto-*

*pelia turtur*, and *H. vilhenai* by Santos Dias (1953) to the form in *Plectopterus gambiensis*. Huff (1932) transmitted *H. maccallumi* from the mourning dove to the domestic pigeon, but Coatney (1953) was unable to transmit *H. columbae* from the pigeon to the mourning dove. Both used the hippoboscid fly, *Pseudolynchia canariensis*, as the vector. There may be strain differences between the different

hosts, but until greater differences than these are brought out, it is probably best to use the name *H. columbae* for all species with halter-shaped gametocytes from columboid birds.

Another name, *H. danilewskyi*, was used by some earlier authors for *H. columbae* in columboid birds. This name was originally given by Kruse (1890) to the species in the crow, *Corvus cornix*, and should not be used for parasites of birds of other orders in the absence of proof that they are the same.

One reservation should be kept in mind regarding reports of halter-shaped *Haemoproteus* from birds. This is that in some cases these protozoa may not be *Haemoproteus* at all but a *Plasmodium* species with halter-shaped or elongate gametocytes, such as *P. fallax* or *P. circumflexum*, which does not have schizonts in the blood at the time of examination.

*Haemoproteus columbae* was found by Giovannoni (1946) in 58% of 159 *C. livia* in southern Curitiba, Brazil; by Singh, Nair and David (1951) in 22% of 214 *C. livia* in Delhi, India; by Huff (1939) in 47% of 188 *Z. macroura* in the United States (mostly in Illinois); by Couch (1952) in 56% of 213 *Z. macroura* in Texas; and by Hanson *et al.* (1957) in 30% of 392 immature *Z. macroura* and in 43% of 72 adult *Z. macroura* in Illinois.

In addition to the above studies in which at least 100 birds of each species were examined, *H. columbae* has been found by various workers in *Columba fasciata* in Arizona and California, in *Columba guinea* in the French Sudan, in *Columba livia*

in various parts of the world, in *Columba oenas* in Italy, in *Columba rufina* in Brazil, in *Columbigallina talpacoti* in Venezuela, in *Plectopterus gambiensis* in Mozambique, in *Streptopelia senegalensis* and *S. vinacea* in the French Sudan, in *S. turtur* in French Morocco, in *Zenaida asiatica* in Arizona and El Salvador, in *Zenaidura macroura* on Cape Cod and in Arizona, California and Nebraska, and in *Ptilinopus iozonus* and *Turtur brehmeri* in zoos.

The second species, *Haemoproteus sacharovi*, was first described by Novy and MacNeal (1904a, b) in the mourning dove, *Zenaidura macroura*, in Michigan. Its gametocytes differ from those of most species of *Haemoproteus* in that when mature they completely fill the host erythrocyte, enlarging and distorting it, and often pushing the host cell nucleus to the edge of the cell.

*H. sacharovi* has been found in both mourning doves and domestic pigeons. It was found by Huff (1939) in 56% of 188 *Z. macroura*, mostly from Illinois; by Couch (1952) in 27% of 213 *Z. macroura* in Texas; and by Hanson *et al.* (1957) in 58% of 392 immature and 43% of 72 mature *Z. macroura* in Illinois.

In addition to the above studies in which at least 100 birds of each species were examined, *H. sacharovi* has been found by various workers in *Columba livia* in Iowa and Nebraska and in *Zenaidura macroura* on Cape Cod and in Arizona, California and Nebraska.

What was almost certainly the same species was described by Franchini (1924) in 3% of 36 *Strepto-*

*pelia turtur* in Italy. He called his form *Leucocytozoon* sp., but his description and figures fit *H. sacharovi* better than they do *Leucocytozoon*.

The above findings refer to studies in which the species of *Haemoproteus* was named. In addition, *Haemoproteus* sp. has been reported without further identification in *Columba cayennensis* in Colombia, *C. picazuro* and *Columbina picui* in Argentina and Brazil, *Oena capensis* in South Africa and Ethiopia, *Ptilinopus superbis* in Australia, *Scardafella squammata* in Brazil, *Sphenurus sphenurus* in India, *Streptopelia capicola* in South Africa, *S. chinensis* in Formosa, *S. decaocto* in Greece, *S. decipiens* in Ethiopia, *S. semitorquata* in the Belgian Congo and Liberia, *S. tranquebarica* in Tonkin, *Treron calva* in the Belgian Congo and Gambia, *Zenaidura auriculata* in Argentina and Colombia, and in *Capoenas nicobarica*, *Columba argentina*, *Columbigallina passerina*, *Geophaps smithii*, *Leptoptila crumeniferus*, *Megaloprepia magnifica*, *Ptilinopus melanospila*, *P. peritatus*, *P. wallacei*, *Treron curvirostra*, *T. delalandi*, *Turacoena manadensis* and *Tympanistria tympanistria* in zoos.

The known geographic distribution and prevalence of *Haemoproteus* in columborid birds are shown in Table 3. The results of surveys in which 100 or more birds were examined have been given above. There have been only 8—of *Columba livia* in Hawaii, Brazil and Delhi, India, of *C. palumbus* in Germany, of *Columbina picui* in Argentina, and of *Zenaidura macroura* in Illinois, Illinois and other states, and Texas.

There have been 32 surveys in

which 10 or more birds were examined. They involved 11 species of columborid birds in 11 countries, including *Columba cayennensis* in Colombia, *C. fasciata* in Colorado, *C. livia* in the United States (Florida, Hawaii, Iowa, Nebraska), Brazil, Italy, Greece, India, French Morocco and the Philippines, *C. oenas* in Italy, *C. palumbus* in Germany and French Morocco, *C. rufina* in Brazil, *Columbina picui* in Argentina, *Streptopelia decaocto* in Greece, *S. turtur* in Italy, Spain and French Morocco, *Zenaidura asiatica* in Arizona, and *Zenaidura macroura* in the United States (Arizona, California, Georgia, Illinois, and other states, Massachusetts, Nebraska, Texas).

The only study of the relation of age to prevalence of *Haemoproteus* was that of Hanson *et al.* (1957) in *Zenaidura macroura*. They found *H. columbae* in 30% of 392 immature and 43% of 72 adult birds in Illinois. The incidence of this species in the immature birds increased steadily with age, from 7 to 8% in very young birds to 70% in older ones. The latter rate was higher than that in the adults.

*H. sacharovi* was present in 58% of the immature and 43% of the adult birds. Its incidence in the immature birds did not increase nearly so sharply with age as did that of *H. columbae*. It was present in 31% of the very young doves, and its incidence fluctuated between 52% and 69% in older immature birds.

Hanson *et al.* (1957) also studied the incidence of *Haemoproteus* in different years from 1948 thru 1954 and in different parts of Illinois. It varied markedly in both categories.

TABLE 4.—Known Geographic Distribution and Prevalence of *Leucocytozoon*\* in Columboid Birds.

Country	Bird Species	Prevalence (%)		
		Present but no reliable figures on prevalence	Surveys in which more than 10 birds were examined	Surveys in which 100 or more birds were examined
<b>EUROPE</b>				
Germany.....	<i>Columba palumbus</i> .....		30	30
England.....	<i>Columba palumbus</i> .....	+		
Corsica.....	<i>Streptopelia turtur</i> .....	+		
Italy.....	<i>Streptopelia turtur</i> .....		3	
Spain.....	<i>Streptopelia turtur</i> .....		100	
<b>ASIA</b>				
Mukteswar, India..	<i>Sphenurus sphenurus</i> ....	+		
Japan.....	<i>Streptopelia orientalis</i> ....		5	5
Tonkin, Vietnam..	<i>Streptopelia tranquebarica</i>	+		
<b>AFRICA</b>				
Pretoria, Un. S. Africa.....	<i>Columba livia</i> .....		82	
French Morocco..	<i>Columba palumbus</i> .....	+		
Transvaal, Un. S. Africa.....	<i>Oena capensis</i> .....	+		
Pietermaritzburg, Un. S. Africa....	<i>Streptopelia capicola</i> ....	+		
Uganda.....	<i>Streptopelia semitorquata</i> .	+**		
Upper Senegal and Nigeria.....	<i>Streptopelia senegalensis</i> ..	+		
French Morocco..	<i>Streptopelia turtur</i> .....		12	
<b>NORTH AMERICA</b>				
Ariz. & Calif.....	<i>Columba fasciata</i> .....	+		
Colorado.....	<i>Columba fasciata</i> .....		18	
California.....	<i>Streptopelia chinensis</i> ....		4	
Ariz. & Calif.....	<i>Zenaidura macroura</i> .....		15	
D. C. & vicinity...	<i>Zenaidura macroura</i> .....	+		
Georgia.....	<i>Zenaidura macroura</i> .....	+		
Illinois.....	<i>Zenaidura macroura</i> .....		1.2***	1.2***
Illinois.....	<i>Zenaidura macroura</i> .....		6.5****	
<b>OTHER</b>				
Mauritius.....	<i>Geopelia striata</i> .....	+		

\* *Leucocytozoon marchouxi* unless otherwise indicated.\*\* *Leucocytozoon* sp. with elongate gametocytes.

\*\*\* Adults.

\*\*\*\* Immature birds.

That of *H. sacharovi* in the immature birds varied from 45% in 1948 to 78% in 1954; in the adults it ranged from 20% in 1953 to 75% in 1951, but these latter figures are based on insufficiently large samples. The incidence of *H. columbae* in the immature birds ranged from 6% in 1950 and 1954 to 43% in 1952; in the adults it ranged from 30% in 1949 and 1950 to 75% in 1952, but this last figure is based on too small a sample. The incidence of *H. sacharovi* in immature birds ranged from 41% in east central Illinois (Champaign County) to 78% in west central Illinois (Hancock County in 1954); in the adults it ranged from 34% in northeast Illinois (Cook County) to 56% in west central Illinois (Hancock County in 1952-53; no adults were studied from this county in 1954). The incidence of *H. columbae* in immature birds ranged from 6% in west central Illinois (Hancock County in 1954) to 42%, also, in west central Illinois (Hancock County in 1952-53); in the adults it ranged from 28% in northeast Illinois (Cook County) to 78% in west central Illinois (Hancock County in 1952-53).

There is no consistent pattern here in the relation of incidence either to year or to location within the state. One can conclude, however, that the results of any survey made at any particular time and place do not necessarily hold true for the same place in a different year or even for a different time in the same year, nor do they necessarily hold true for a different place not too far away during the same time of the same year.

The life cycle of *Haemoproteus*

*columbae* has been studied by Aragão (1908), Adie (1915, 1924) and Huff (1942) among others. The only proven vector is the hippoboscid fly, *Pseudolynchia canariensis* (syns., *Lynchia maura*, *L. lividicolor*, *L. capensis*). In addition, Aragão (1916) stated that *Microlynchia pusilla* is a vector in South America, but gave no experimental evidence. Baker (1957) found that *H. columbae* from the English wood pigeon (*Columba palumbus*) would undergo sporogony in the hippoboscid, *Ornithomyia avicularia*, but 6 attempts to infect domestic pigeons by bite or injection of infected louse-flies failed.

Huff (1932) found that *Pseudolynchia canariensis* was a vector of *H. sacharovi* and used it to transmit this parasite from the mourning dove to the pigeon.

It is highly unlikely, however, that hippoboscids are the only vectors of either *H. columbae* or *H. sacharovi*. As Hanson *et al.* (1957) pointed out, hippoboscids are extremely rare on mourning doves, especially in the northern states, yet both species of *Haemoproteus* are common in them. The discovery by Fallis and Wood (1957) that biting midges (*Culicoides*) are vectors of *H. nettionis* of ducks suggests that they may also transmit *H. columbae* and *H. sacharovi*.

Altho the natural vectors of *H. columbae* and *H. sacharovi* in Illinois are unknown, the findings of Hanson *et al.* (1957) of a much higher incidence of *H. sacharovi* in considerably younger mourning doves than *H. columbae* permits one to conclude either that the vectors of the two species are different or that

TABLE 5.—Known Geographic Distribution and Prevalence of *Toxoplasma gondii* in Columboid Birds.

Country	Bird Species	Prevalence (%)		
		Present but no reliable figures on prevalence	Surveys in which more than 10 birds were examined	Surveys in which 100 or more birds were examined
<b>NORTH AMERICA</b>				
Dist. Columb.....	<i>Columba livia</i> .....		12	
Ohio .....	<i>Columba livia</i> .....		5	
New York.....	<i>Columba livia</i> .....		1	
Tennessee.....	<i>Columba livia</i> .....		6	

(Identifications Confirmed by Mouse Inoculation, Dye Test or Both)

TABLE 6.—Known Geographic Distribution and Prevalence of *Toxoplasma*, *Lankesterella* or Similar Protozoa in Columboid Birds\*.

Country	Bird Species	Prevalence (%)		
		Present but no reliable figures on prevalence	Surveys in which more than 10 birds were examined	Surveys in which 100 or more birds were examined
<b>ASIA</b>				
Portuguese India..	<i>Columba livia</i> .....	+		
<b>AFRICA</b>				
Belgian Congo....	<i>Columba livia</i> .....	+		
<b>SOUTH AND CENTRAL AMERICA</b>				
Brazil.....	<i>Columba livia</i> .....	+		
Panama.....	<i>Columba livia</i> .....	+		
Brazil.....	<i>Columba rufina</i> .....		88	
Brazil.....	<i>Columbigallina talpacoti</i> ..	+		

\* (Identifications by Microscopic Examination Only.)

*H. sacharovi* has a shorter prepatent period than *H. columbae*. However, the marked difference in relative incidence in immature doves in the same locality (Hancock County) in different years (60% for *H. sacha-*

*rovi* and 42% for *H. columbae* in 1952-53 as compared with 78% for *H. sacharovi* and 6% for *H. columbae* in 1954) makes it possible to speculate that the vectors may be different.

*Haemoproteus columbae* is only slightly pathogenic. Infected birds usually show no signs of disease. In relatively heavy infections, the birds may appear restless and go off feed, and anemia may result from destruction of erythrocytes, but this is unusual. The schizonts occur in the endothelial cells of the blood vessels of the lungs, liver and spleen. The liver and spleen of affected birds may be enlarged and dark with pigment.

*H. sacharovi* appears to be only slightly if at all pathogenic in the mourning dove. Becker, Hollander and Pattillo (1956) considered that it caused the enlarged, purplish livers which they encountered in dressing domestic pigeon squabs from an infected flock; there was apparently no other evidence of disease.

*Leucocytozoon*. A single valid species of *Leucocytozoon*, *L. marchouxi* Mathis and Leger, 1910 has been described from columborid birds (Levine, 1954). This species has rounded gametocytes. In addition, Minchin (1910) described but did not name a form with elongate gametocytes from a collar-dove, *Streptopelia semitorquata*, in Uganda; it has not been encountered since.

*Leucocytozoon marchouxi* was found in 30% of 128 *C. palumbus* in Germany by Böing (1925); in 5% of 111 *S. orientalis* in Japan by Ogawa (1912); and in 1.2% of 392 immature and 6.5% of 72 adult *Zenaidura macroura* in Illinois by Hanson *et al.* (1957).

The known geographic distribution and prevalence of *Leucocytozoon* in columborid birds are shown in Table 4. The results of surveys in which 100 or more birds were ex-

amined have been given above. There have been only 3 such surveys—of *C. palumbus* in Germany, of *S. orientalis* in Japan, and of *Z. macroura* in Illinois. There has been a total of only 10 surveys in which 10 or more birds were examined. They involved 7 species of columborid birds in 6 countries—*Columba fasciata* in the United States, *C. livia* in South Africa, *C. palumbus* in French Morocco and Germany, *Streptopelia chinensis* in the United States, *S. orientalis* in Japan, *S. turtur* in French Morocco and Spain, and *Zenaidura macroura* in Illinois, Arizona and California.

In addition to these surveys, *Leucocytozoon* has been found in *Columba fasciata* in Colorado and Arizona or California, in *C. livia* in Pretoria, South Africa (the only record of this genus from the domestic pigeon), in *C. palumbus* in England and French Morocco, in *Geopelia striata* on Mauritius, in *Oena capensis* in South Africa, in *Sphenurus sphenurus* in India, in *Streptopelia capicola* in South Africa, in *S. chinensis* in California, in *S. senegalensis* in Upper Senegal and Nigeria, in *S. tranquebarica* in Vietnam, in *S. turtur* on Corsica and in French Morocco, Spain and Italy, in *Zenaidura macroura* in Georgia, the District of Columbia area, Arizona and California, and in *Columba argentina*, *C. vitiensis* and *Megaloprepia magnifica* in zoos. To these surveys should be added quite a few others in which *Leucocytozoon* was not found; those can be identified by comparison with the data on *Haemoproteus* (Table 3).

Altho Hanson *et al.* (1957) found *L. marchouxi* in a higher proportion

of adults than of immature mourning doves, they pointed out that their figures are misleading. Of the 10 infected birds in their survey, 5 were adults, 1 was a juvenile 3 to 4 months old, and 4 were nestlings. Since the great majority of immature doves in their survey were juveniles, the prevalence of patent infections with *L. marchouxi* is probably considerably less than 1% in juveniles, while that in nestlings is probably considerably more. The youngest positive dove was only 14 days old (Levine, 1954).

The vectors of *L. marchouxi* are unknown. They are presumably species of *Simulium* like the vectors of other species of *Leucocytozoon*. However, the absence of *Leucocytozoon* in columboid birds in South and Central America despite the relatively large number of surveys which have been carried out there suggests that suitable vectors may not exist in this area.

Nothing is known about the pathogenicity of *L. marchouxi*. There were no signs of illness in the infected mourning doves seen by Levine (1954) and Hanson *et al.* (1957), even tho 4 of them were nestlings and 1 was only 14 days old.

*Toxoplasma*, *Lankesterella*, and *Similar Protozoa*. There have been a number of reports of *Toxoplasma*, *Lankesterella* or morphologically similar protozoa in columboid birds (Tables 5, 6). Most have been in the domestic pigeon. In the great majority of cases, these organisms have been assigned to the genus *Toxoplasma*, altho de Mello (1915) called one form, which he found in a domestic pigeon in Portuguese India, a hemogregarine and de Mello

*et al.* (1917) named another form from the same host *Leucocytozoon franciae*. (This generic name is no longer accepted; it is a synonym of *Hepatozoon*.) However, due to the confusion which is only now being resolved regarding the identity of these parasites, one cannot accept any identification of *Toxoplasma* in birds unless it has been confirmed by animal inoculation or by serologic means.

There have been four reports of *Toxoplasma gondii* in domestic pigeons which fulfill this requirement. Feldman and Sabin (1949) found *T. gondii* in 5% of 20 pigeons in Cincinnati, Ohio, confirming their identification by mouse inoculation. Manwell and Drobeck (1951) found *T. gondii* in 1% of 60 pigeons in Syracuse, New York, confirming their identification by use of the dye test. Jacobs, Melton and Jones (1952) found *T. gondii* in 12% of 80 pigeons in Washington, D. C., confirming their identification by the dye test and mouse inoculation. Gibson and Eyles (1957) found *T. gondii* in 6% of 16 pigeons in Memphis, Tennessee, confirming their identification by mouse inoculation.

In other reports, what may have been either *Toxoplasma* or *Lankesterella* or possibly some other genus have been found in the domestic pigeon in Portuguese India, the Belgian Congo, Brazil and Panama, in *Columba rufina* and *Columbigallina talpacoti* in Brazil, and in *Ducula concinna* in a zoo.

#### DISCUSSION

A total of 174 papers is included in the present analysis. Of these, 22 are from Europe, 22 from Asia, 32

from Africa, 64 from North America, 32 from South and Central America, and 2 from Australia. This number of papers might lead one to believe that the blood parasites of columborid birds are rather well known. This is far from the case. In his *Check-list of birds of the world*, Peters (1937) listed 61 genera and 320 species of birds in the order. The most common parasite genus in these birds is *Haemoproteus*. Levine and Kantor (1959) pointed out on the basis of their compilation that *Haemoproteus* had been reported from 19 genera and 45 species of the order Columborida, but that these comprise only 31% of the known host genera and 14% of the known host species. *Plasmodium* had been reported from 20% of the genera and 7% of the species, *Leucocytozoon* from 11% of the genera and 5% of the species, *Trypanosoma* from 8% of the genera and 2% of the species, and *Toxoplasma* or something similar from 5% of the genera and 1% of the species. No parasites at all have been reported from two genera, *Oreopelia* and *Gallicolumba*, which contain 15 and 18 species, respectively, and only two cases have been reported from the genus *Ducula*, which contains 37 species.

Levine and Kantor's compilation included birds in zoos. If these are omitted, then *Haemoproteus* has been found in only 20% of the known host genera and 8% of the known host species, *Plasmodium* in 11% of the genera and 3% of the species, *Leucocytozoon* in 10% of the genera and 4% of the species, *Trypanosoma* in 8% of the genera and 2% of the species, and *Toxoplasma* or something similar in 3% of the genera

and 1% of the species.

But this is not all. A great many of these records were more or less casual. The authors examined a series of blood smears from a miscellany of birds and made no attempt to identify the parasites beyond genus. Levine and Kantor (1959) found on analysis of their compilation that the parasite species had been named in 51% of 180 reports of *Haemoproteus*, 64% of 47 reports of *Plasmodium*, 32% of 31 reports of *Leucocytozoon*, 60% of 10 reports of *Trypanosoma* and 75% of 16 reports of *Toxoplasma* and similar forms. If reports on birds in zoos are omitted, these figures become 58% of 138 reports of *Haemoproteus*, 62% of 26 reports of *Plasmodium*, 35% of 26 reports of *Leucocytozoon*, 60% of 10 reports of *Trypanosoma*, and 77% of 13 reports of *Toxoplasma* and similar forms. In 43% of the total of 213 records, the species name of the parasite was not given. Furthermore, in only 41 (24%) of the 174 papers in the present analysis were 10 or more birds of a single species examined and the prevalence of infection given, and in only 12 (7%) of them were 100 or more birds examined and the prevalence of infection given.

Further light can be thrown on the reliability of our present information on geographic distribution and prevalence of these protozoa by considering the number of examinations on which it is based. I have done this for *Haemoproteus*, the genus on which we have most information. In quite a few reports, the number of birds examined was not stated and may have been relatively small. The data assembled for the

remainder are based on the examination of blood smears from 2515 birds—296 from Europe, 356 from Asia, 53 from Africa, 1391 from North America, and 419 from South and Central America. These examinations, may I remind you, were made between 1891 and 1957. A geographic distribution map might appear to be fairly well filled in, but it would be based on a pitifully small population sample.

A great deal thus remains to be done before we can claim to have really good information on the blood parasite situation in the great majority of columboid birds in most parts of the world. Casual observations are all very well, but extensive, careful, thoro surveys would be much more valuable. Furthermore, surveys made at one time of year or on one age group of host may not represent the situation at another time of year or on another age group of the same host. We lack information on all this.

Not only is our information on the geographic distribution and incidence of blood parasites of columboid birds scattered and superficial, but our information on their life cycles, vectors and pathogenesis is also poor. We do not know the role of these parasites in the interplay of favorable and unfavorable factors on which their hosts' survival in nature depends. We suspect that *Trypanosoma* and *Haemoproteus* may be relatively non-pathogenic; we think that *Plasmodium* and *Toxoplasma* may be more or less pathogenic—we know that they can be in the laboratory, at least; but we do know what to say about *Leucocytozoon* and *Lankesterella*. Here, too,

more information is needed.

Another problem which needs further study is the role of the domestic pigeon as a possible reservoir of *Toxoplasma*. The surprisingly high mean incidence of 8% in a total of 176 birds examined by Feldman and Sabin (1949), Manwell and Drobeck (1951), Jacobs, Melton and Jones (1952) and Gibson and Eyles (1957) in different surveys suggest that this bird may well be an important reservoir.

#### LITERATURE CITED

- ADIE, H. 1915. The sporogony of *Haemoproteus columbae*. Ind. J. Med. Res., 2: 671-680.
- ADIE, H. 1924. The sporogony of *Haemoproteus columbae*. Bull. Soc. Pathol. Exot., 17: 605-613.
- ARAGÃO, H. DE B. 1908. Über den Entwicklungsgang und die Übertragung von *Haemoproteus columbae*. Arch. Protist., 12: 154-167.
- ARAGÃO, H. DE B. 1916. Pesquisas sobre o "*Haemoproteus columbae*." Brazil Med., 30: 361-362.
- BAKER, J. R. 1956a. Studies on *Trypanosoma avium* Danilewsky 1885. II. Transmission by *Ornithomyia avicularia* L. Parasitology, 46: 321-334.
- BAKER, J. R. 1956b. Studies on *Trypanosoma avium* Danilewsky 1885. III. Life cycle in vertebrate and invertebrate hosts. Parasitology, 46: 335-352.
- BAKER, J. R. 1957. A new vector of *Haemoproteus columbae* in England. J. Protozool., 4: 204-208.
- BECKER, E. R., W. F. HOLLANDER and W. H. PATILLO. 1956. Naturally occurring *Plasmodium* and *Haemoproteus* infection in the common pigeon. J. Parasitol., 42: 474-478.
- BENNETT, G. F. 1961. On the specificity and transmission of some avian trypanosomes. Can. J. Zool., 39: 17-33.
- BENNETT, G. F. and A. M. FALLIS. 1960. Blood parasites of birds in Algonquin Park, Canada and a discussion of their transmission. Can. J. Zool., 38: 261-273.
- BÖING, W. 1925. Untersuchungen über Blutschmarotzer bei einheimischen Vogelwild. Zentr. Bakteriolog. I. Orig., 95: 312-327.
- CARINI, A. 1912. Sur un nouvel hématozoaire du pigeon. Compt. Rend. Soc. Biol., 73: 396-398.

- CELLI, A. and F. SANFELICE. 1891a. Sui parassiti del globulo rosso nell' uomo e negli animali. Ann. Ist. Sper., Univ. Roma (N.S.), 1:33-63.
- CELLI, A. and F. SANFELICE. 1891b. Ueber die Parasiten des rothen Blutkörperchens im Menschen und in Thieren. Fortschr. Med., 9:499-511, 541-552, 581-586.
- COATNEY, G. R. 1933. Relapse and associated phenomena in the Haemoproteus infection of the pigeon. Am. J. Hyg., 18:133-160.
- COATNEY, G. R. 1938. A strain of *Plasmodium relictum* from doves and pigeons infective to canaries and the common fowl. Am. J. Hyg., 27:380-389.
- COATNEY, G. R. and E. WEST. 1938. Some blood parasites from Nebraska birds. II. Am. Midland Naturalist, 19:601-612.
- COUCH, A. B., JR. 1952. Blood parasites of some common Texas birds. Field and Lab., 20:146-154.
- COVALEDA, ORTEGA, J. and J. GALLEGU BERENQUER. 1950. Hemoproteus aviaries. Rev. Iber. Parasitol., 10:141-185.
- FALLIS, A. M. and D. M. WOOD. 1957. Biting midges (Diptera: Ceratopogonidae) as intermediate hosts for Haemoproteus of ducks. Can. J. Zool., 34:425-435.
- FELDMAN, H. A. and A. B. SABIN. 1949. Skin reactions to toxoplasmic antigen in people of different ages without known history of infection. Pediatrics, 4:798-804.
- FRANCHINI, G. 1924. Observations sur les hématozoaires des oiseaux d'Italie. (2<sup>e</sup> note). Ann. Inst. Pasteur, 38:470-515.
- GIBSON, C. L. and D. E. EYLES. 1957. *Toxoplasma* infections in animals associated with a case of human congenital toxoplasmosis. Am. J. Trop. Med. Hyg., 6:990-1000.
- GIOVANNONI, M. 1946. Fauna parasitologica paraense. I. *Haemoproteus columbae* Celli e Sanfelice. 1891 em *Columba livia domestica* nos pombais de Curitiba. Arq. Biol. Tecnol., 1:19-24.
- HANSON, H. C., N. D. LEVINE, C. W. KOSSACK, S. KANTOR and L. J. STANNARD. 1957. Parasites of the mourning dove (*Zenaidura macroura carolinensis*) in Illinois. J. Parasitol., 43:186-193.
- HERMAN, C. M., W. C. REEVES, H. E. McCLURE, E. M. FRENCH and W. McD. HAMMON. 1954. Studies on avian malaria in vectors and hosts of encephalitis in Kern County, California. I. Infections in avian hosts. Am. J. Trop. Med. Hyg., 3:676-695.
- HUFF, C. G. 1932. Studies on *Haemoproteus* of mourning doves. Am. J. Hyg., 16:618-623.
- HUFF, C. G. 1935. *Plasmodium hexamerium* n. sp. from the bluebird, inoculable to canaries. Am. J. Hyg., 21:274-277.
- HUFF, C. G. 1939. A survey of the blood parasites of birds caught for banding purposes. J. Am. Vet. Med. Assoc., 94:615-620.
- HUFF, C. G. 1942. Schizogony and gametocyte development in *Leucocytozoon simondi*, and comparisons with *Plasmodium* and *Haemoproteus*. J. Inf. Dis., 71:18-32.
- HUFF, C. G. and D. F. MARCHBANK. 1955. Changes in infectiousness of malarial gametocytes. I. Patterns of oocyst production in seven host-parasite combinations. Exp. Parasitol., 4:256-270.
- HUFF, C. G., D. F. MARCHBANK, A. H. SAROFF, P. W. SCHRIMSHAW and T. SHIROISHI. 1950. Experimental infections with *Plasmodium fallax* Schwetz isolated from the Uganda tufted guinea fowl *Numida meleagris major* Hartlaub. J. Nat. Malaria Soc., 9:307-319.
- JACOBS, L., M. L. MELTON and F. E. JONES. 1952. The prevalence of toxoplasmosis in wild pigeons. J. Parasitol., 38:457-461.
- KRANEVELD, F. C. and M. MANSJOER. 1954. Onderzoekingen over bloedparasiten. VIII. Over een Trypanosoma van de tortelduif (*Streptopelia chinensis tigrina*). Hemera Zoa, 61:9-20.
- KRUSE, W. 1890. Ueber Blutparasiten. Virchow's Arch., 121:359.
- LAVERAN, M. A. and A. PETIT. 1909. Sur une hémamibe du *Melopelia leucoptera* L. Compt. Rend. Soc. Biol., 66:952-954.
- LEVINE, N. D. 1954. *Leucocytozoon* in the avian order Columbiformes, with a description of *L. marchouxi* Mathis and Leger 1910 from the mourning dove. J. Protozool., 1:140-143.
- LEVINE, N. D. and S. KANTOR. 1959. Check-list of blood parasites of birds of the order Columbiformes. Wildl. Dis., 1(1):38 pp.
- MANWELL, R. D. and H. P. DROBECK. 1951. Mammalian toxoplasmosis in birds. Exp. Parasitol., 2:221-235.
- MATHEY, W. J., JR. 1955. Two cases of *Plasmodium relictum* infection in domestic pigeons in the Sacramento area. Vet. Med., 50:318.
- MELLO, I. F. DE. 1915. Preliminary note on a new haemogregarine found in the pigeon's blood. Ind. J. Med. Res., 3:93-94.

- MELLO, I. F. DE and L. J. BRAS DE SA. 1916. A contribution to the study of haemoprotozoa in Portuguese India. *Ind. J. Med. Res.*, 3:731-737.
- MELLO, I. F. DE, L. J. BRAS DE SA, L. DE SOUSA, A. DIAS and R. NORONHA. 1917. Hématozoaires et pseudo-hématozoaires de l'Inde Portugaise. *Ann. Sci. (Fac. Med.) Porto*, 3:181-200.
- MINCHIN, E. A. 1910. Report on a collection of blood-parasites made by the Sleeping Sickness Commission, 1908-1909, in Uganda. *Rep. Sleep. Sick. Comm. Roy. Soc.*, 10:73-86.
- NOVY, F. G. and W. J. MACNEAL. 1904a. Trypanosomes and bird malaria. *Am. Med.*, 8:932-934.
- NOVY, F. G. and W. J. MACNEAL. 1904b. Trypanosomes and bird malaria. *Med. News, N. Y.*, 85:1144-1146.
- NOVY, F. G. and W. J. MACNEAL. 1905a. Trypanosomes and bird malaria. *Proc. Soc. Exp. Biol. Med.*, 2:23-28.
- NOVY, F. G. and W. J. MACNEAL. 1905b. On the trypanosomes of birds. *J. Inf. Dis.*, 2:256-308.
- OGAWA, M. 1912. Notizen über die blutparasitischen Protozoen bei Japanischen Vögeln. *Arch. Protist.*, 24:119-126.
- PETERS, J. L. 1937. Check-list of birds of the world. Vol. 3. Harvard Univ. Press.
- RENJIFO-SALCEDO, S., C. SANMARTIN and J. DE ZULUETA. 1952. A survey of the blood parasites of vertebrates in eastern Colombia. *Acta Tropica*, 9:151-169.
- SANTOS DIAS, J. A. T. 1953. Resultados de um reconhecimento zoológico no Alto Limpopo efectuado pelos Drs. F. Zumpt e J. A. T. Santos Dias. V. Hematozoários das aves: generos *Haemoproteus* Kruse e *Carpanoplasma* n. gen. Mocambique, 73:61-99.
- SERGEANT, ED. 1941a. Trypanosome de la tourterelle "a longue queue" *Streptopelia* sp. (?) du Sahara Nigérien. *Arch. Inst. Pasteur Algérie*, 19:29.
- SERGEANT, ED. 1941b. A propos du trypanosome de la "tourterelle à longue queue" du Sahara Nigérien. *Arch. Inst. Pasteur Algérie*, 19:431.
- SINGH, J., C. P. NAIR and A. DAVID. 1951. Five years' observation on the incidence of blood protozoa in house sparrows (*Passer domesticus* Linnaeus) and in pigeons (*Columba livia* Gmelin) in Delhi. *Ind. J. Malariol.*, 5:229-233.
- WOLFSON, F. 1937. Experimental infections in owls and pigeons with plasmodia of the wood thrush. *Am. J. Hyg.*, 26:53-59.
- WOLFSON, F. 1940. Exo-erythrocytic schizogony associated with the wood-thrush strain of *Plasmodium cathemerium* in relation to the species of the host. *Am. J. Hyg.*, 31(C):26-35.
- WOOD, S. and C. M. HERMAN. 1943. The occurrence of blood parasites in birds from southwestern United States. *J. Parasitol.*, 29:187-196.

Manuscript received March 1, 1962.