talis, and the natural *Leishmania* infection rate of approximately 2% in this species, as described above, present a parasitological pattern differing widely from that in Kenya. Kenya workers do not report the presence of *P. papatasi*, a species that commonly bites man in central Sudan but which is found only in villages and is not a vector of Sudanese kala-azar. We might interpolate that in Egypt, where *P. papatasi* is the only species of man-biting sandfly, cutaneous leishmaniasis, caused by *L. tropica*, is present but kala-azar, caused by *L. donovani*, is absent.

Vertebrate reservoirs of kala-azar in both Kenya [y] and the Sudan do not appear to include domestic dogs. In the Sudan, Dr Harry Browne of NAMRU-3 obtained negative results from examination of approximately 275 domestic dogs associated with kala-azar patients or hamlets.

In Kenya, during ten years of work four *Leishmania* strains were isolated from a ground squirrel (*Xerus*) and three grass gerbils (*Tatera robusta*); the epidemiological significance of these limited findings is unknown.[y]

In the same sites in which we collected infected sandflies in Sudanese acacia forests, we have isolated *Leishmania* strains from four grass rats (*Arvicanthis*), one spiny mouse (*Acomys*), one genet (*Genetta*), and one serval (*Felis serval*). The infections in hamsters produced by these strains from wild rodents and carnivores are apparently identical to those produced by Sudanese strains of *Leishmania donovani* from humans and by *Leishmania* from wildcaught *P. orientalis* as well as from *P. orientalis* fed on human kala-azar patients. Presumably, rodent and carnivore infections are involved in human kala-azar, which in the Paloich area may be a zoonosis. In the town of Malakal, 100 miles (160 km) south of Paloich, man-biting sandflies are absent. *Leishmania* was isolated from a domestic rat (*Rattus rattus*) and from a spiny mouse (*Acomys*) in Malakal town. Presumably in this urban centre a rodent-sandfly-rodent cycle is in operation without involvement of man.

[y] Heisch, R. B. (1963) *E. Afr. med. J.*, **40**, 359.

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Anopheles as Vectors of Animal Malaria Parasites

by R. S. Bray *and* P. C. C. Garnham. *London School of Hygiene and Tropical Medicine, London, England*

In the incrimination of the main vectors of human malaria, the dissection of wild-caught *Anopheles* for the presence of sporogonic forms of plasmodia has traditionally played an important role. The regular recurrence of sporozoite infections in species of *Anopheles* known to be closely associated with man has usually been regarded as convincing proof that the species concerned is implicated in the transmission of human malaria. It has also been recognized for many years that, in a comparatively small number of anopheline species, sporozoite infections occur which must be of non-human origin on the grounds that the anopheline species concerned are sylvan or non-domestic, and have little or no contact with man.

In recent years the progress of the malaria eradication programmes has made it necessary to reappraise long-established criteria, and to review with a more critical eye the significance and interpretation of infection rates in vectors and suspect vectors. In addition, the extension of the programme to many new and unsurveyed countries or areas has revealed situations that cannot readily be explained simply by reference to the one or two species that have long been regarded as the main vectors in a particular area. Furthermore, there are many suspect vectors that feed readily on both man and animals, and it is difficult to know if the infections are of human or animal origin.

There is an increasing number of cases where field

TABLE 1

PROVEN *ANOPHELES* VECTORS OF ANIMAL PARASITES IN NATURE

Anopheles	Parasite	Host	Locality	Author
A. balabacensis introlatus	*P. cynomolgi*	*Macaca irus*? (monkey)	Malaya	Warren & Wharton (1963)
	P. fieldi	*Macaca irus*?	Malaya	Warren & Wharton (1963)
A. dureni	*P. berghei*	*Thamnomys surdaster* (rat)	Katanga Province, Congo	Vincke & Lips (1950)
	P. vinckei	*Thamnomys surdaster*		Rodhain (1952)
A. hackeri	*P. cynomolgi*			Warren & Wharton (1963)
	P. inui	*Macaca irus* and/or	Malaya	Warren & Wharton (1963)
	P. knowlesi	*Presbytis cristatus* (monkeys)		Wharton & Eyles (1961)
	P. coatneyi			Eyles et al. (1962)
	P. fieldi			Warren & Wharton (1963)
A. leucosphyrus	*P. inui*	*Macaca irus*	Malaya	Warren & Wharton (1963)
A. smithi rageaui	*P. atheruri*	*Atherurus africanus* (porcupine)	Cameroon	Mouchet et al. (1957)
A. umbrosus	*P. traguli*	*Tragulus javanicus* (mouse-deer)	Malaya	Wharton et al. (1962, 1963)
A. vanthieli (=*A. faini vanthieli*)	*P. atheruri*	*Atherurus africanus*	Kivu Province, Congo	Berghe et al. (1958)

investigators, faced with the problem of persistent transmission in problem areas, are finding it difficult to evaluate the situation because of the ever-present doubt about the human or non-human origin of infections found by the routine dissection of all suspect species. In those cases where the investigator has strong grounds for believing that infections found in the local anophelines may be non-human, attempts to find confirmatory evidence from the literature have proved extremely difficult because of the scattered nature of the available records, and because not all relevant information has yet appeared in print.

The present note represents an attempt to bring together all this scattered information—published and unpublished—in such a way as to be of some value in the interpretation of field problems in malaria eradication (see Tables 1, 2 and 3). In this connexion it is of considerable significance that, since the first draft of this report was prepared in 1963, the new information that has come in from South-East Asia alone has necessitated extensive additions and revisions.

There is some recent evidence that mosquitos other than *Anopheles* may be experimentally infected with simian plasmodia (Warren et al., 1962) and therefore that some natural infections of *Mansonia* and *Aedes* may possibly be due to *Plasmodium* species of mammals. Work on this aspect of the parasitology of malaria is now proceeding in India and Malaya and has been started in the Congo (Leopoldville).

It is hoped that the present summary will stimulate further critical research and lead eventually to a more exact technique for distinguishing the sporozoites and oocysts of human malarias from those of animal origin—e.g., the fluorescent antibody technique developed by Corradetti et al. (1964).

* * *

The authors wish to acknowledge the invaluable help of the late Dr D. E. Eyles in compiling the lists.

TABLE 2

SUSPECTED *ANOPHELES* VECTORS OF ANIMAL MALARIA PARASITES IN NATURE

Anopheles	Suspected parasite	Suspected host	Locality	Author
A. baezai	*P. traguli*	*Tragulus javanicus*	Malaya	Wharton et al. (1962, 1963)
A. barberellus	*P. cephalophi*	Antelope	Liberia	Bray (1964)
A. concolor	*P. cephalophi*	Antelope	Congo	
A. crucians	*P. praecox*?	*Passer*? (sparrow)	USA	Frohne et al. (1950) Hunninen et al. (1950)
A. donaldi	?	?	Malaya	
A. letifer	? *P. traguli*	? *Tragulus javanicus*	Sarawak Malaya	 Wharton et al. (1962, 1963)
A. machardyi	*P. anomaluri*?	*Anomalurus*? (flying squirrel)	Tanganyika	Pringle (1960)
A. maculipalpis	?	?	Cameroon	
A. marshalli	?	?	Congo	
A. nili	?	?	Liberia	
A. pretoriensis	?	?	S. Rhodesia	
A. pujutensis	*Plasmodium spp.* of Malayan monkeys	*Macaca* and *Presbytis*	Malaya	Warren & Wharton (1963)
A. riparis	?	?	Malaya	
A. roperi	*P. traguli*	*Tragulus javanicus*	Malaya	Wharton et al. (1963)
A. rufipes	*P. cephalophi*?	*Cephalophus grimmi*? (duiker antelope)	Upper Volta; S. Rhodesia	Office de la Recherche Scientifique et Technique Outre-Mer (1959)
A. smithi rageaui	*Plasmodium sp.* (to be named)	*Roussettus* (fruit bat)	Ghana	Van der Kaay, J.[a]

[a] Personal communication.

TABLE 3

ANOPHELES CAPABLE OF TRANSMITTING ANIMAL MALARIA PARASITES EFFICIENTLY IN THE LABORATORY

Anopheles	Parasite	Author
A. albimanus	*P. brasilianum* [a]	Clarke & Dunn (1931)
	P. bastianellii	Eyles (1960b)
	P. praecox	Hunninen (1951)
	P. gallinaceum [a]	Eyles (1960b)
A. annularis	*P. cynomolgi*	Indian Research Fund Association (1947)
	P. knowlesi?	Jaswant Singh et al. (1949)
A. atroparvus	*P. gonderi* [a]	Rodhain & Van Hoot (1940)
	P. cynomolgi	Shortt & Garnham (1948)
	P. bastianellii	Garnham (1959)
	P. inui [a]	Garnham (1951)
	P. gallinaceum	
A. aztecus	*P. shortti*	Shortt et al. (1963)
	P. berghei [b]	Perez-Reyes (1953)
	P. cynomolgi	
	P. bastianellii	Garnham (1959)
	P. gonderi [a]	Garnham et al. (1958)
	P. knowlesi [a]	Garnham et al. (1957)
	P. inui	Sezen (1956)
	P. brasilianum [a]	Garnham et al. (1963)
A. bezai	*P. traguli*	Wharton et al. (1962)
A. balabacensis introlatus	*P. bastianellii* [a]	Eyles, D. E. [c]
A. barbirostris	*P. cynomolgi*	Indian Research Fund Association (1947)
A. crucians	*P. praecox* [a]	Hunninen et al. (1950)
A. culicifacies	*P. cynomolgi*	Indian Research Fund Association (1947)
A. fluviatilis	*P. cynomolgi*?	Ramakrishnan & Mohan [d]
A. freeborni	*P. bastianellii*	Eyles (1960a, 1960c)
	P. cynomolgi	Eyles (1960a, 1960c)
	P. inui	Eyles (1960c)
	P. praecox	Hunninen (1951)
	P. gallinaceum	Eyles (1952)
A. gambiae	*P. cynomolgi*	
A. hyrcanus	*P. cynomolgi*	Indian Research Fund Association (1947)
A. kochi	*P. cynomolgi*	Green (1932)
A. letifer	*P. traguli*	Wharton et al. (1962)
A. lesteri	*P. bastianellii*	Eyles, D. E. [c]
A. maculatus	*P. cynomolgi*	Green (1932)
	P. bastianellii	Warren et al. (1962)
A. philippinensis	*P. bastianellii*	Eyles, D. E. [c]
A. quadrimaculatus	*P. cynomolgi*	Coggeshall (1941)
	P. bastianellii [a]	Beye et al. (1961)
	P. inui	Eyles (1960c)
	P. gallinaceum	Haas & Akins (1947)
	P. lophurae	Coggeshall (1941)
	P. praecox	Hunninen et al. (1950)
	P. fallax [a]	Huff et al. (1950)
A. splendidus	*P. cynomolgi*	Mulligan (1935)
A. stephensi	*P. knowlesi* [a]	Jaswant Singh et al. (1949)
	P. cynomolgi	Ramakrishnan & Mohan [d]
	P. bastianellii	Garnham (1959)
	P. inui [a]	Sezen (1956)
	P. shortti	Shortt et al. (1963)
A. subpictus	*P. cynomolgi*	Indian Research Fund Association (1947)
	P. praecox	Mayne (1928)
A. sundaicus	*P. bastianellii*	Eyles, D. E. [c]
A. tarsimaculatus	*P. brasilianum*	Clarke & Dunn (1931)
A. vagus	*P. cynomolgi*	Green (1932).

[a] Dubious efficiency as a vector. [b] On one occasion only. [c] Personal communication.

[d] Ramakrishnan, S. P. & Mohan, B. N. (1962) *An enzootic focus of simian malaria in* Macaca radiata *Geoffroy of Nilgiris, Madras State, India* (unpublished document WHO/Mal/332).

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Molluscicidal Time-Concentration Relationships of Organo-tin Compounds *

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The importance of exposure time in relation to molluscicidal activity is becoming increasingly apparent as more evidence comes to hand indicating that the shortest interval affording maximum efficiency varies for different molluscicides. This was recognized but not fully comprehended in our studies on molluscicide susceptibilities of stage-size arrays of *Australorbis glabratus* with 6- and 24-hour

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