Studies on Simian Malaria in Brazil *

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Recent work on the possibility of transmitting monkey malaria to man has increased the interest in studies on simian plasmodia. Research on this subject is being performed in Brazil under the auspices of the World Health Organization.

Two species of *Plasmodium* have been previously found in monkeys in Brazil: the quartan-like *Plasmodium brasilianum*, discovered by Gonder & Berenberg-Gossler [a] in a *Cacajao calvus* from the upper Amazon (north Brazil), and *P. simium*, which is close to *P. vivax*, and has been described by Fonseca [b] from a howler monkey, *Alouatta fusca*, from the State of São Paulo (south Brazil). *P. brasilianum* has never been encountered again in Brazil, but has been found several times in other countries of South and Central America.[c, d, e] In spite of extensive studies in various countries, several aspects of its ecology remain unsettled.[f, g, h] Of *P. simium*, only the morphology of the blood forms has been known.

The aims of the present work, started in São Paulo, are to ascertain the prevalence of malarial infection of monkeys and its seasonal variation, the infectivity of simian plasmodia to species of monkeys other than the original hosts and, possibly, to man; to determine what are the vectors; and to study the possibility of the transmission of simian plasmodia to man in nature.

Field work is being performed in a Government forest reservation where howler monkeys are relatively abundant (the Horto Florestal da Cantareira on the outskirts of the city of São Paulo). This work includes the capture and examination of monkeys and the capture of mosquitos on baits placed on the ground and on platforms in the forest canopy, their identification and their examination for sporozoites. Since the capture of living howlers by means of traps or anaesthetizing bullets has proved to be rather difficult, most of them have been shot. While moribund, their heart blood is obtained for the preparation of thick and thin films and for preservation for future inoculations; pieces of viscera are taken for smears and histological sections. The monkeys captured alive are splenectomized and submitted to daily blood examination and other observations, and used for transmission experiments.

Prevalence of infections and behaviour of P. simium *in* Alouatta fusca

Up to the end of August 1964 a total of 35 *Alouatta* had been examined. Plasmodia were found in the blood of 12, and three others, although negative for parasites, revealed malarial pigment in the spleen and other viscera—evidence of previous infection. Nearly all the positives harboured *P. simium*. In one, however, the parasites were quartan-like and another showed a mixed infection by *P. simium* and a quartan-type *Plasmodium*; in two the parasites were few and it was not possible to determine the species or type. Five *Alouatta* were captured alive; all others were shot. Only two of the living specimens were adults, the others being babies whose mothers had been killed. Both adults caught alive were positive (for *P. simium*) and were kept in the laboratory for 42 and 60 days respectively. Their blood was examined for a short period two to four times a day and subsequently daily. They originally showed a very light infection (as did nearly all other howlers), but after splenectomy the parasitaemia increased extraordinarily; in one case from six to a peak of more than 225 000 parasites per mm^3 of blood on the 24th day. In both, parasitaemia decreased after three to four weeks, but in one it rose again soon before death. Fever, anaemia, weight loss, hair loss and diarrhoea were observed. Blood examination revealed schizogony to be of the tertian

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[a] Gonder, R. & Berenberg-Gossler, H. von (1908) *Malaria, Lpz.*, **1**, 47.

[b] Fonseca, F. (1951) *Mem. Inst. Osw. Cruz*, **49**, 543.

[c] Clark, H. C. (1931) *Amer. J. trop. Med.*, **11**, 11.

[d] Clark, H. C. & Dunn, L. H. (1931) *Amer. J. trop. Med.*, **11**, 1.

[e] Dunn, F. L. & Lambrecht, F. L. (1963) *J. Parasit.*, **49**, 316.

[f] Taliaferro, W. H. (1932) *Amer. J. Hyg.*, **16**, 429.

[g] Taliaferro, W. H. & Taliaferro, L. G. (1934) *Amer. J. Hyg.*, **21**, 1.

[h] Contacos, P. G. et al. (1963) *Science*, **142**, 676.

type, very regular after the first weeks, and accompanied by high fever (up to 41.5°C). Schizonts were much more numerous in spleen smears than in the peripheral blood.

Experimental infection of other monkeys with P. simium

In order to verify the susceptibility of other species of monkeys to *P. simium* and with a view to isolating strains of this parasite, inoculations of blood of heavily infected *Alouatta* were performed (intraperitoneally and subcutaneously) in capuchin monkeys (*Cebus* sp.), rhesus monkeys (*Macaca mulatta*), squirrel monkeys (*Saimiri sciureus*) and marmosets (*Callithrix jacchus*).

No evidence of infection was obtained in two splenectomized *Cebus* or in two rhesus (one splenectomized), but results were different with the other species inoculated. One splenectomized adult *Saimiri sciureus* developed a severe infection, parasitaemia reaching 212 000 per mm³ of blood on the twentieth day, but decreasing thereafter. Its blood was injected into a young, splenectomized specimen of the same species, which also became intensely parasitized and died on the eighth day. In two splenectomized adults, one showed plasmodia in blood smears only from the second to the fourth days after the inoculation; in the other parasitaemia rose to 270 000 per mm³ on the eleventh day, gradually decreasing afterwards. In sum, of four *S. sciureus* inoculated, all showed patent parasitaemia; one young specimen died, heavily parasitized; in one adult the parasitaemia was very low and transient, disappearing after the fourth day; in the remaining adults blood parasites reached a very high level but decreased later. Studies are being carried out on the periodicity of schizogony and the course of infection in this experimental host.

The marmoset (*Callithrix jacchus*) has also been shown to be susceptible to *P. simium*: one splenectomized adult specimen inoculated with blood from the first experimentally infected *S. sciureus* showed patent parasitaemia from the second day until the twenty-second day, always, however, of a low or moderate degree.

Thus two species of primates have been found susceptible to *P. simium* besides its original host: one, the squirrel monkey (*Saimiri sciureus*), might be a convenient laboratory animal for the study of this *Plasmodium*, because it is a common species in north Brazil, relatively easy to obtain in São Paulo, easy to keep in the laboratory, small (weighing about 500 g), good-tempered, easy to handle and not very expensive. The marmoset (*Callithrix jacchus*) is even smaller (about 300 g), easier to obtain in southern Brazil and much less expensive, but it is too restive, more aggressive and difficult to handle. The other monkeys tested (*Cebus* sp. and *Macaca mulatta*) are much larger, more expensive and difficult to deal with, and have not proved infectable so far. The original host, *Alouatta fusca*, is difficult to catch alive and usually does not live long in captivity.

Search for vectors of P. simium *in nature*

This part of the study has been hampered by an unusual drought followed by a severe winter, leading to a very low density of mosquitos. Forty-four captures were performed, all on human bait, 28 at ground level and 16 on the platforms in the forest canopy. Most mosquitos caught were sabethines (genera *Trichoprosopon*, *Phoniomyia* and *Wyeomyia*) and culicines (*Aedes*, *Culex* and a few *Haemagogus*); the few anophelines belonged to the species *Anopheles (Kerteszia) cruzii*, *A. (Myzorhynchella) lutzi* and *A. (Nyssorhynchus) strodei*, only the first of which was obtained on the platforms. Dissections for examination for sporozoites have been negative so far.

Transliteration from Cyrillic characters

The " International System for the Transliteration of Cyrillic Characters ", set out in Recommendation ISO/R9-1954 (E) of the International Organization for Standardization, is normally used in the *Bulletin of the World Health Organization* for personal names, titles of publications, etc. However, papers accepted for publication may contain names transliterated differently, and if the original Cyrillic spelling is not recognizable inconsistencies may occur.

For convenience the transliteration from Russian according to ISO/R9 is given below:

Translittération des Caractères cyrilliques

Le « Système international pour la translittération des caractères cyrilliques » présenté dans la Recommandation ISO/R9-1954 (F) de l'Organisation internationale de Normalisation est généralement utilisé dans le *Bulletin de l'Organisation mondiale de la Santé* pour les noms de personnes, les titres de publications, etc. Cependant des articles acceptés pour publication peuvent contenir des noms translittérés différemment et si l'orthographe cyrillique originale n'est pas reconnaissable un manque d'uniformité peut s'ensuivre.

A toutes fins utiles, la translittération du russe selon la recommandation ISO/R9 est indiquée ci-après:

Cyrillic character Caractère cyrillique	Transliteration from Russian Translittération du russe	Examples and remarks Exemples et observations	Cyrillic character Caractère cyrillique	Transliteration from Russian Translittération du russe	Examples and remarks Exemples et observations
А, а	a	Адрес = Adres	У, у	u	Утро = Utro
Б, б	b	Баба = Baba	Ф, ф	f	Физика = Fizika
В, в	v	Вы = Vy	Х, х	h	Химический = Himičeskij
Г, г	g	Глава = Glava Голова = Golova	Ц, ц	c	Центральный = Central'nyj
			Ч, ч	č	Часы = Časy
Д, д	d	Да = Da	Ш, ш	š	Школа = Škola
Е, е (ё) [1]	e (ë)	Ещё = Eščë	Щ, щ	šč	Щека = Ščeka
Ж, ж	ž	Журнал = Žurnal	(medial, médial)	″or″ ″ou″	In modern Russian, where ′ sometimes replaces medial ъ, transliteration is still ″. En russe moderne, où le ′ remplace quelquefois le ъ médial, la translittération reste ″.
З, з	z	Звезда = Zvezda			
И, и	i	Или = Ili	Ъ, ъ		
Й, й	j	-ый, -ий, -ой = -yj, -ij, -oj			
К, к	k	Как = Kak	(final)	(Not transliterated. Non translittéré.)	
Л, л	l	Любить = Ljubit'			
М, м	m	Муж = Muž			
Н, н	n	Нижний = Nižnij			
О, о	o	Общество = Obščestvo	Ы, ы	y	Был = Byl
П, п	p	Первый = Pervyj	Ь, ь	′or′ ′ou′	Маленький = Malen'kij
Р, р	r	Рыба = Ryba	Э, э	ê	Это = Êto
С, с	s	Сестра = Sestra	Ю, ю	ju	Южный = Južnyj
Т, т	t	Товарищ = Tovarišč	Я, я	ja	Яйцо = Jajco

[1] Cyrillic ё to be transliterated by ë only when the diacritical appears in the original. Le ё cyrillique ne doit être translitteré par ë que lorsque la diacritique apparaît dans l'original.